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File Code: December 19, 2000
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Mr. Donald Campbell
Superintendent
Harpers Ferry National Historical Park
P.O. Box 65
Harpers Ferry, WV 25425

Dear Mr. Campbell:

Enclosed is a gypsy moth biological evaluation for Harpers Ferry National Historical Park conducted in October 2000.

In brief, gypsy moth populations at Loudoun Heights, Maryland Heights and Short Hill sections at Harpers Ferry NHP are generally healthy, building and sufficient to cause widespread heavy defoliation on approximately 1,232 acres in 2001. In order to protect foliage and prevent subsequent tree mortality, our recommendation is to either aerially apply two applications of *Bacillus thuringiensis* variety *kurstaki* (*Btk*) at the rate of 36 BIUs per acre or two applications of Gypchek at the rate of 2 x 10" OB's in a total mix of 1 gallon per acre.

Our office would like to thank Dale Nesbit for his assistance in conducting the egg mass survey in October.

If you have any questions concerning the biological evaluation, please feel free to call Brad Onken at (304) 285-1546 or Karen Felton at (304) 285-1556.

Sincerely,

JOHN W. HAZEL
Field Representative
Morgantown Field Office

Enclosure

Cc: Bill Hebb, Harpers Ferry NHP
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BIOLOGICAL EVALUATION OF GYPSY MOTH

at

Harpers Ferry National Historical Park

2000

Prepared by

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ABSTRACT

On October 2-4, 2000, USDA Forest Service and USDI Park Service personnel conducted a gypsy moth egg mass survey at Harpers Ferry National Historic Park. The purpose of this survey was to determine population densities to assess the potential for defoliation and the need for treatment in 2001. Current populations are sufficient to cause heavy (60-100%) defoliation on approximately 1,232 acres at Harpers Ferry NHP in 2001. Treatment to prevent defoliation is recommended.

METHODS

The survey method used in this survey was the $1/40^{th}$ acre plot. Gypsy moth survey plots were randomly selected based upon available host trees (mainly oaks), size of sample area and uniformity between egg mass counts. The plots consisted of a tally of all new (2000) egg masses observed on the overstory trees, understory vegetation, ground litter and duff in an 18.6′ radius sample area. The total number of egg masses observed for each plot was multiplied by 40 to determine the number of egg masses per acre. The survey results were then averaged to estimate egg mass density.

Egg mass length was measured at most of the plots to determine the overall "health" of the existing population and as a measure of egg mass fecundity. The average egg mass length (measured in millimeters) and egg mass density (egg masses per acre) were used to estimate defoliation potential (Liebhold et al., 1993).

RESULTS

The location of the survey plots are shown in Figures 1a - 1c and the survey results are summarized in Tables 1-3. Survey plots were established at Loudoun Heights, Maryland Heights, and Short Hill areas at Harpers Ferry NHP. Parkwide, egg mass densities ranged form 0-44,280 and averaged 7,288 egg masses per acre. At Loudoun Heights, Maryland Heights and Short Hill, egg mass densities averaged 2,280, 12,250, and 7,335 egg masses per acre, respectively. No egg masses were found in the remaining area of the park. Egg mass lengths ranged from 22-40 mm and averaged 31 mm.

DISCUSSION

The basic guidelines used to evaluate the risk of defoliation include: previous defoliation events; number of egg masses/acre; size and condition of the egg masses; available preferred food (mainly oaks); and risk of larval blow-in following egg hatch. Potential defoliation is categorized as: light (1-30 percent), moderate (31-60 percent), and heavy (61-100 percent).

The survey results indicate that widespread heavy defoliation is likely to occur on approximately 232, 720, and 280 acres at Loudoun Heights, Maryland Heights and Short Hill sections, respectively, at Harpers Ferry NHP in 2001 (Figure 2).

This conclusion is further supported when egg density is used as a means of predicting defoliation. Moore and Jones (1987) found that estimating the mean fecundity would increase

Figure 1a --Gypsy moth egg mass survey plot locations at Harpers Ferry National Historical Park (Loudoun Heights), October 2, 2000.

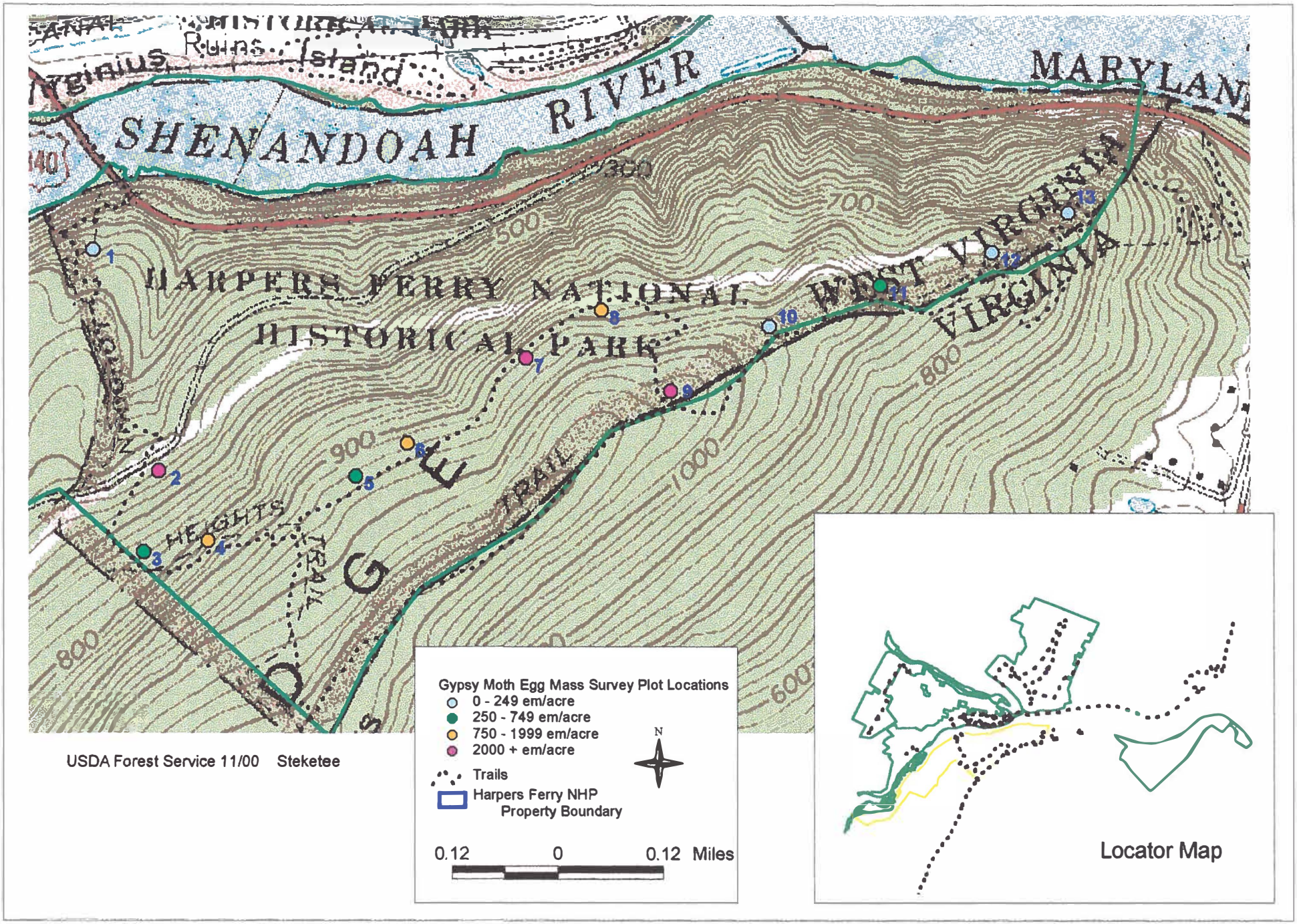
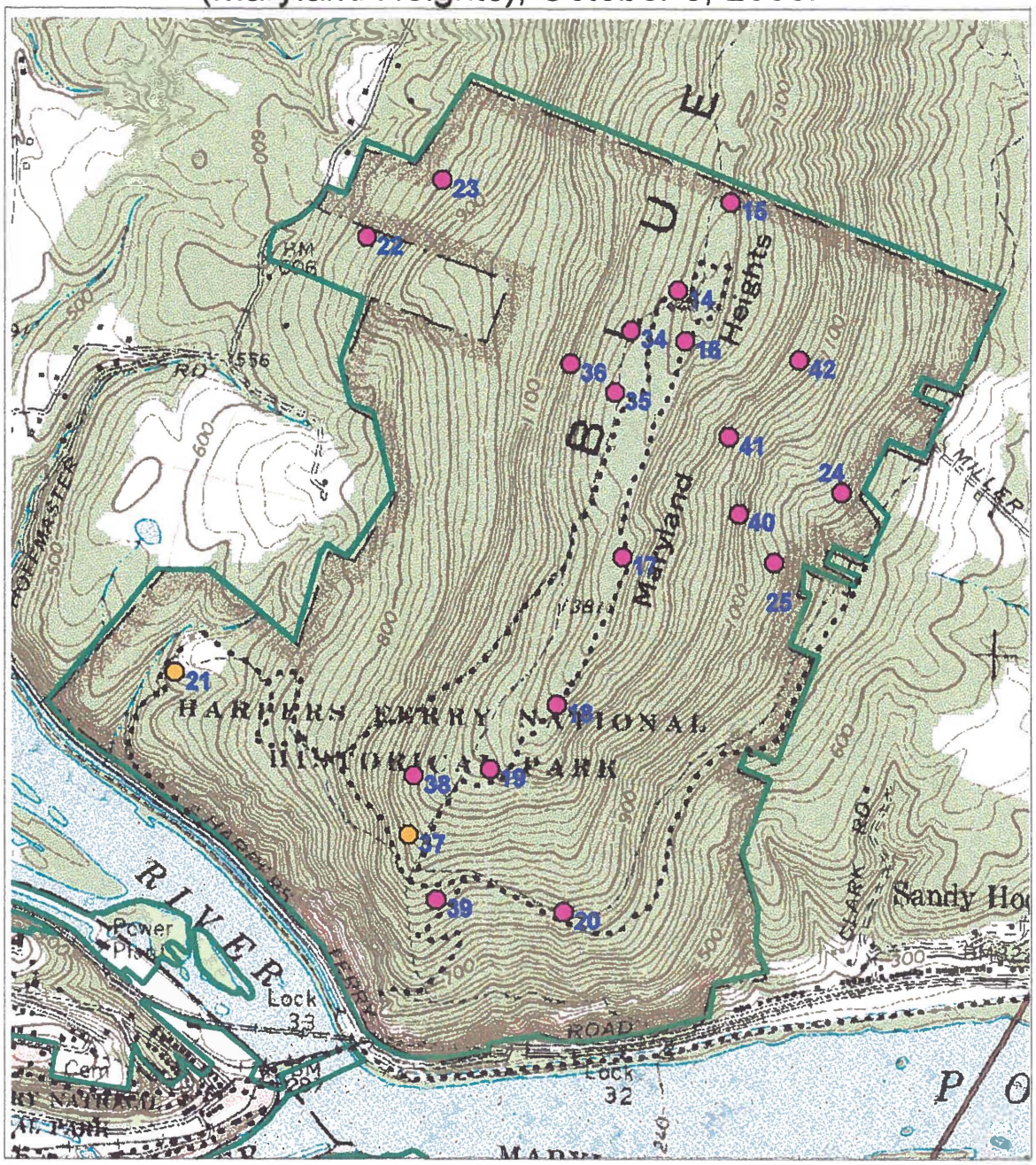
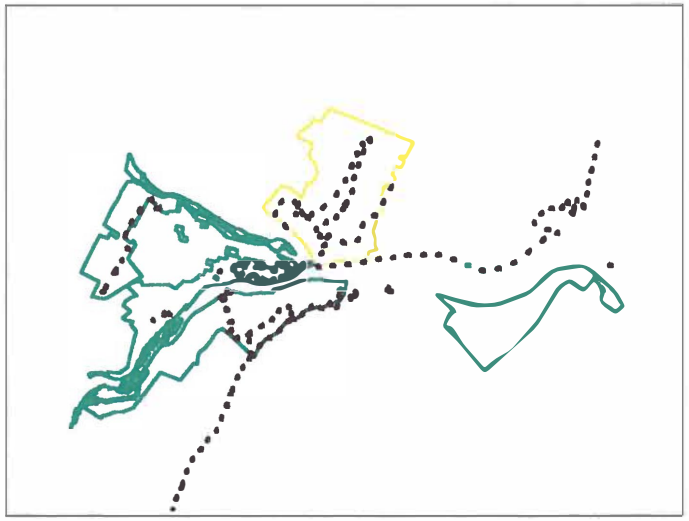


Figure 1b --Gypsy moth egg mass survey plot locations at Harpers Ferry National Historical Park (Maryland Heights), October 3, 2000.



Locator Map



Gypsy Moth Egg Mass Survey Plot Locations
- 0 - 249 em/acre
- 250 - 749 em/acre
- 750 - 1999 em/acre
- 2000 + em/acre
- Trails
- Harpers Ferry NHP Property Boundary

N

0.1 0 0.1 0.2 0.3 Miles

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Figure 1c --Gypsy moth egg mass survey plot locations at Harpers Ferry National Historical Park (Short Hill), October 4, 2000.

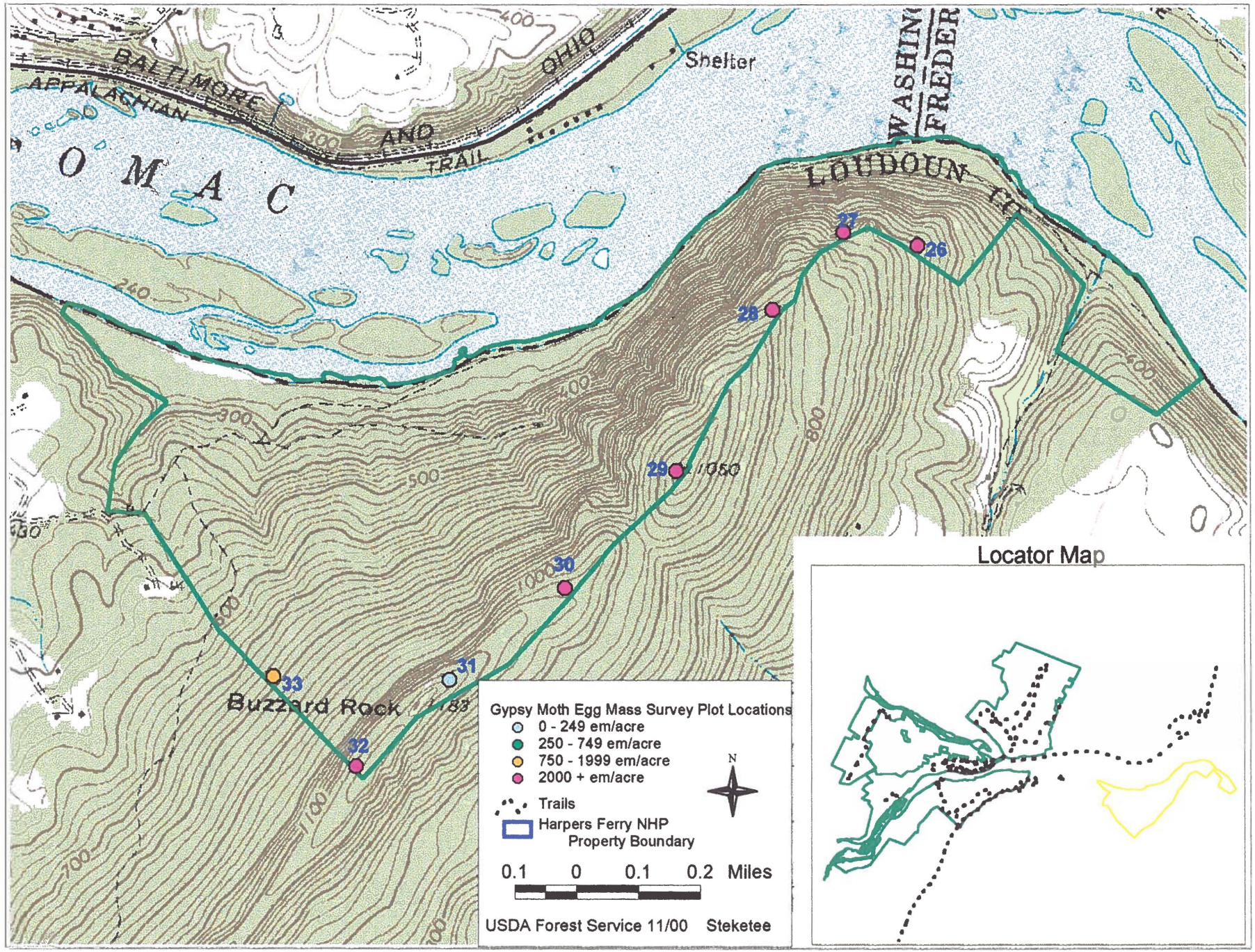


Table 1—Gypsy moth egg mass survey results at Harpers Ferry National Historical Park (Loudoun Heights), October 2, 2000.

Plot Number	*Number EM/Acre*
1	0
2	4,840
3	440
4	1,840
5	440
6	1,840
7	14,840
8	1,800
9	3,040
10	40
11	480
12	0
13	40
EM/Acre Range = 0-14,840	EM size Range (mm) = 27-38
EM/Acre Average = 2,280	EM Size Average = (mm) = 32

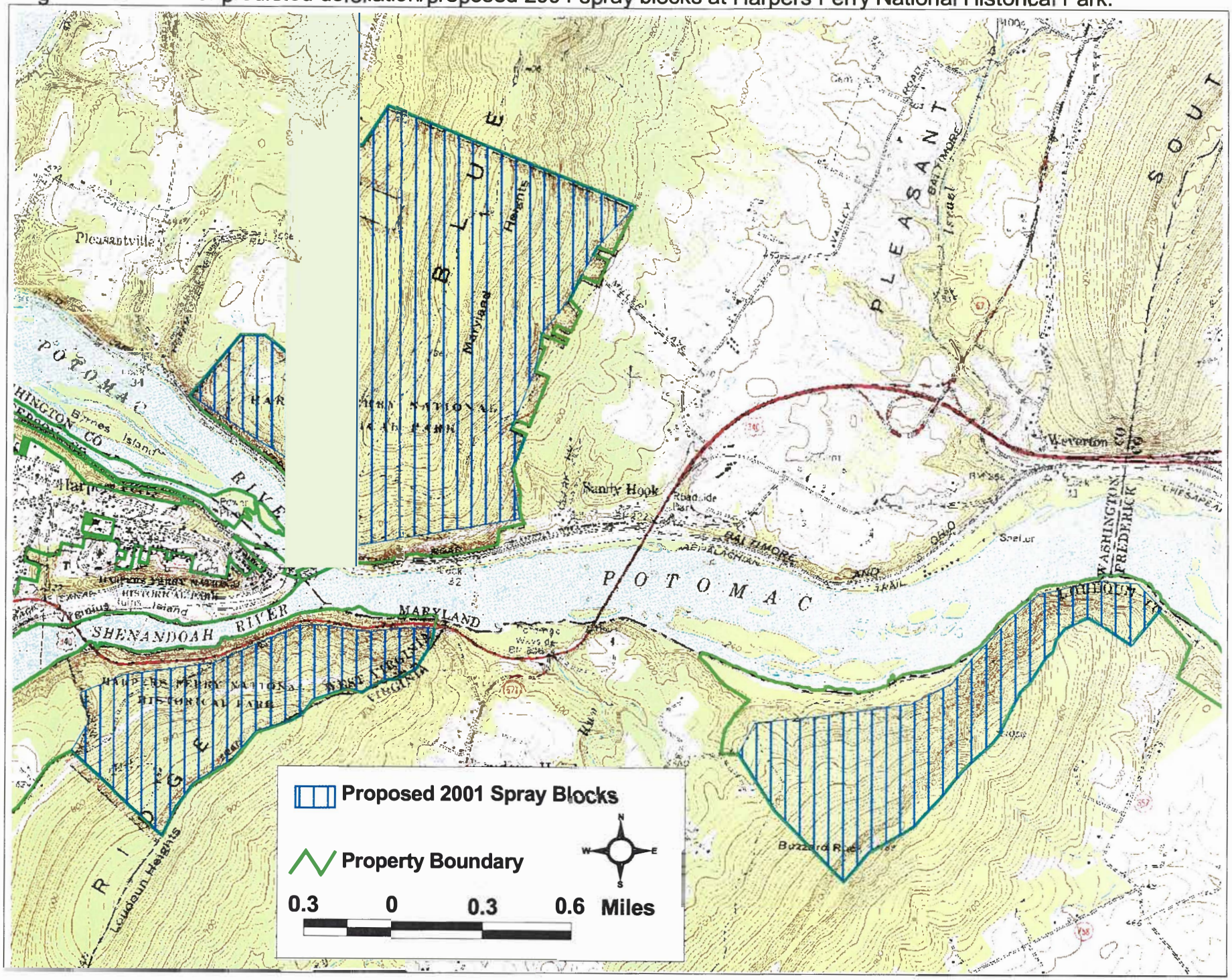
Table 2—Gypsy moth egg mass survey results at Harpers Ferry National Historical Park (Maryland Heights), October 3, 2000.

Plot Number	*Number EM/Acre*
14	16,240
15	11,280
16	6,880
17	3,440
18	4,080
19	25,360
20	4,640
21	1,360
22	2,200
23	31,080
24	5,280
25	5,040
34	20,080
35	10,320
36	6,200
37	1,080
38	4,240
39	15,440
40	4,600
41	44,280
42	34,120
EM/Acre Range = 1,080-44,280	EM size Range (mm) = 27-40
EM/Acre Average = 12,250	EM Size Average = (mm) = 33

Table 3—Gypsy moth egg mass survey results at Harpers Ferry National Historical Park (Short Hill), October 4, 2000.

Plot Number	*Number EM/Acre*
26	20,960
27	4,960
28	15,120
29	7,560
30	5,240
31	120
32	3,680
33	1,040
EM/Acre Range = 120-20,960	EM size Range (mm) = 22-34
EM/Acre Average = 7,335	EM Size Average = (mm) = 27

Figure 2. -- Areas of predicted defoliation/proposed 2001 spray blocks at Harpers Ferry National Historical Park.



the precision of gypsy moth density estimates and that a linear relationship exists between egg mass length and fecundity. Further work by Liebhold et al., (1993) demonstrates that the product of the mean egg mass length (mm) and egg mass density provides a more precise means of estimating population densities and predicting defoliation. Using Liebhold's model, Figure 3 shows how this information can be used to correlate the predicted defoliation of an area. Accordingly, this translates to a projected defoliation level ranging from 63-93 percent at all three areas. This represents an overall average and since egg mass densities and host type are not evenly distributed, actual defoliation will vary somewhat from tree to tree throughout the areas.

Based on existing egg mass densities and the general size of egg masses, gypsy moth populations appear to be building and healthy throughout most of the areas surveyed at Harpers Ferry NHP. The average egg mass length at most of the survey plot locations is 27 mm or larger. Egg masses larger than 25 mm typically indicate healthy populations with no obvious stress from either the gypsy moth nucleopolyhedrosis virus (NPV) or the *Entomophaga maimaiga* fungus, two of the primary natural control agents that often express themselves in declining populations. Both gypsy moth fungus and virus activity were minimal this past year at Harpers Ferry National Historical Park. Although it is still possible that either the gypsy moth fungus or the NPV could cause the general collapse of the gypsy moth population next year, it is unlikely that populations will collapse prior to a significant defoliation event occurring in 2001.

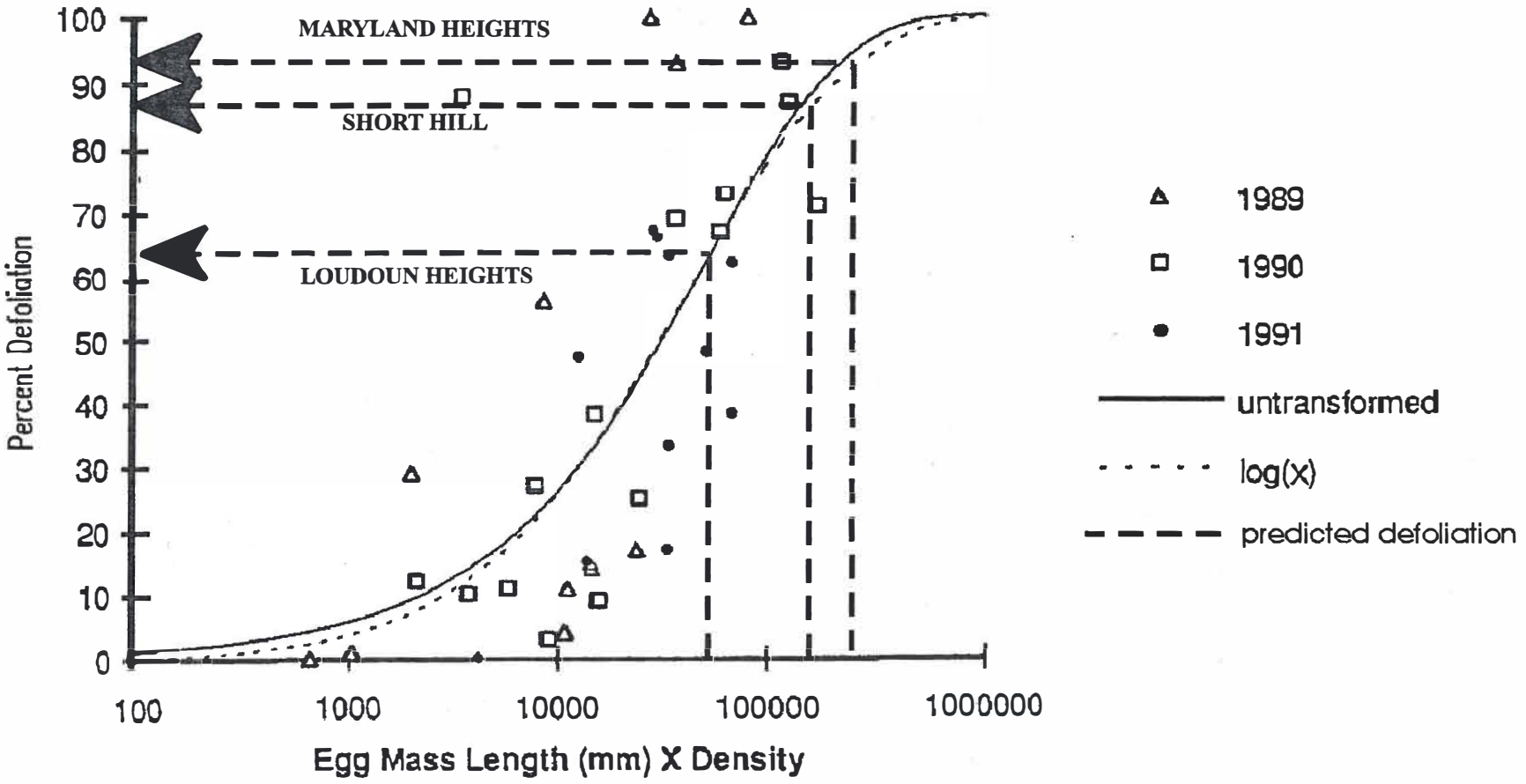
Predicting the extent of tree mortality that would occur after one year's defoliation is difficult, however, a stand of trees that is not stressed by other agents during or immediately following a single heavy defoliation will likely pull through with only minor branch dieback and minimal mortality. A more immediate and direct effect of defoliation is through the loss of oak mast. This occurs primarily from caterpillar feeding damage to flowers as well as foliage. Excessive foliage loss causes a lack of carbohydrates, which results in the abortion of immature acorns. It is possible to have several years of complete acorn failure during and following years of moderate to heavy defoliation (Gottschalk, 1990).

In general, trees that are defoliated in excess of 60 percent normally refoliate the same growing season. Such events cause the trees to expend valuable energy reserves to refoliate, and consequently cause the trees' health to deteriorate. Depending on the condition of the trees at the time of defoliation, reduced growth, mast abortion, branch dieback or in some cases tree mortality, has occurred following a single year of heavy defoliation. Should subsequent defoliation occur the following year, the impact is compounded. Trees that receive light-moderate defoliation (< 60 percent) are not likely to refoliate and there is probably no significant impact other than a reduction in growth, reduction of mast and possibly some minor branch dieback.

Trees at greater risk are those that are presently stressed from other factors, such as soil compaction from roads, sidewalks, parking lots, machinery and/or heavy foot travel; over maturity; drought; shock due to recent timber cutting activities; previous year(s) defoliation; and other insect and disease related problems.

In 2000, approximately 19 acres of moderate and 181 acres of heavy defoliation occurred at Harpers Ferry NHP. If these areas should be defoliated again in 2001, the likelihood of mortality increases. The growing season this past year was excellent. However, it is impossible to predict next year's growing season. If it is droughty, and there is widespread heavy defoliation

Figure 3.--Predicted defoliation at Harpers Ferry National Historical Park (Loudoun Heights, Maryland Heights, and Short Hill) in 2001 based on egg mass length and density.



Scatter plot of the product of mean egg mass length and egg mass density versus mean defoliation. Extracted from Liebhold et al. (1993).

(especially in those areas previously defoliated in 2000), the chances of increased tree mortality are likely to occur at Loudoun Heights, Maryland Heights, and Short Hill areas in 2001.

The Allegheny National Forest (1988) and the West Virginia Division of Forestry (1997) provide examples of the potential tree mortality that can occur. On the Allegheny National Forest, untreated stands consisting of 40-80 percent oak, the average loss of basal area (mainly oaks) was about 16 percent (range 3-28) percent) following one year of defoliation and 26 percent (range 10-43 percent) after two consecutive years of defoliation. In a 1986 study area in eastern West Virginia where oak species accounted for 63-78 percent of the species composition, a loss of 25 percent of the total oak sawtimber and 14 percent of the total oak poletimber occurred after one year of moderate to heavy defoliation. In these examples, droughty conditions likely contributed to the level of mortality.

Management Options

For 2001, two management options have been evaluated for managing gypsy moth populations at Harpers Ferry NHP. The intervention options are offered based upon the following two treatment objectives: 1) protect host tree foliage to prevent tree mortality; and 2) reduce gypsy moth population below the treatment threshold to the extent possible. Each is discussed below.

No Action Option

It is possible that gypsy moth populations could collapse on their own due to the presence of nucleopolyhedrosis virus (NPV) or the more recently recognized fungal pathogen, *Entomophaga maimaiga.* In areas with defoliating level gypsy moth populations (greater than 750 egg masses per acre) viral epizootics generally manifest themselves after significant tree defoliation has already occurred. Gypsy moth populations will usually peak in 2-3 years once they reach defoliating levels and then collapse as a result of NPV or fungal activity. Residual populations following such a collapse will likely remain at low densities for 3-6 years before rebuilding to defoliating levels. Although it is not possible to accurately assess such events with the information at hand, it is unlikely that a collapse will occur since most of these areas are newly infested and there is an abundance of large healthy egg masses.

Large numbers of gypsy moth caterpillars and defoliation has been show to impact competing native herbivore arthropods. Sample et al. (1996) showed short-term impacts of both species richness and abundance occurred following light to moderate defoliation events in study plots in West Virginia. It is likely that impacts would be greater as the size of the area and intensity of defoliation increases and be more long term, should extensive tree mortality occur.

Should this option be selected, it is likely that widespread heavy defoliation will occur at Loudoun Heights, Maryland Heights, and Short Hill areas at Harpers Ferry NHP in 2001.

Microbial Insecticide Option

Btk: The only biological insecticide currently registered and commercially available for gypsy moth control is the microbial insecticide *Bacillus thuringienis* variety *kurstaki (Btk).* This insecticide is available through several manufacturers and has been used extensively in suppression projects throughout the U.S. in both forested and residential areas. *Btk* is a bacterium that acts specifically against lepidopterous larvae as a stomach poison and therefore

must be ingested. The major mode of action is by mid-gut paralysis which occurs soon after feeding. This results in a cessation of feeding, and death by starvation. *Btk* is persistent on foliage for about 7-10 days.

Btk has been shown to impact other non-target caterpillars that are exposed of the treatment and are actively feeding. An example of the potential impacts is provided by a study conducted by Miller (1990) in Oregon and Samples, et al. (1996) in West Virginia. Miller's study involved a large-scale eradication program where three consecutive applications of *Btk* were applied to a 5,000 acre treatment block within a single season. On Garry oak, Miller found that species richness was significantly reduced in treated areas during all 3 years of the study while the total number of immature native Lepidoptera rebounded after the second year. In the Sample study, the areas treated with *Btk* were 50 acre plots and only a single treatment applied. Here too, both species richness and the total numbers of native macro-lepidopterous caterpillars and adults were reduced but only for less than 1-year. The difference in duration of the impacts between these studies is probably the result of the number of treatment applications applied and the size of the treatment area involved.

Btk formulations are available as flowable concentrates, wettable powders, and emulsifiable suspensions. The normal application rates range from 24-36 billion international units (BIUs) per acre in a single or double application. *Btk* can be applied either undiluted or mixed with water for a total volume of ½-1 gallon per acre. With proper application, foliage protection and some degree of population reduction can be expected with one application and with two applications both foliage protection and a greater degree of population reduction are likely. Because *Btk* is a biological insecticide, the degree of population reduction varies and may depend on, at least in part, the selected application rate, relative health of the population (building vs. declining), population densities, weather (rain and temperature), the feeding activity of the larvae following treatment, and the actual potency of the product.

Gypchek: A second microbial insecticide that is registered and available in limited quantities is the formulated nucleopolyhedrosis virus called Gypchek. This product is not available commercially but is produced in limited quantities by a cooperative effort of the USDA Forest Service and the Animal Plant Health Inspection Service (APHIS). The active ingredient in Gypchek formulations has a very narrow host range (lymnatriids) and occurs naturally in gypsy moth populations. Normally the virus reaches epizootic proportions when gypsy moth populations reach high densities as a result of increased transmission within and between gypsy moth generations. The application of Gypchek to gypsy moth populations simply expedites this process by increasing the exposure of the virus at an earlier stage. Healthy, feeding gypsy moth caterpillars become infected by ingesting contaminated foliage and soon stop feeding and die.

The efficacy of Gypchek treatments to reduce gypsy moth populations has been quite variable. Because of the short period of viral activity on foliage (3-5 days) as well as other biological factors such as feeding activity and weather conditions, it has been difficult at best to project treatment efficacy. Most often foliage protection can be achieved but significant reductions in gypsy moth densities do not always occur. Should inadequate population reduction occur, areas would need to be treated again the following year.

The normal application rate of Gypchek is 2×10^{11} occlusion bodies (OB's) per acre applied in two applications, 3-5 days apart. Due to the limited supply, priority is first given to state and federal cooperators that need to deal with federally listed threatened and endangered species

associated with gypsy moth treatments. However, there will be sufficient quantities available in 2001 to provide the National Park Service for gypsy moth treatments.

Alternatives

With the previously described options in mind, the following alternatives are offered.

Alternative 1. -No action

Alternative 2. -One aerial application of *Btk* at the rate of 36 BIUs in a total mix of ¾ gallon per acre.

Alternative 3 -Two aerial application of *Btk*, as in alternative 2, applied 4-7 days apart.

Alternative 4 -Two aerial applications of Gypchek at the rate of 2×10^{11} OB's in a total mix of 1 gallon per acre, applied 3-5 days apart.

RECOMMENDATIONS

As previously stated, gypsy moth populations at Harpers Ferry NHP (Loudoun Heights, Maryland Heights and Short Hill) are generally healthy, building and sufficient to cause widespread heavy defoliation in 2001. In order to protect tree foliage and prevent subsequent tree mortality, our recommendation is to aerially treat 1,232 acres as described in either alternative 3 or 4. Either alternative would likely provide foliage protection. Alternative 3 is more likely to reduce gypsy moth populations. Given the density and relatively good health of the gypsy moth population at Harpers Ferry, it is very likely re-treatment will be needed in 2002, regardless of which alternative is selected.

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